Biology 150 - Fall Semester
Introductory Workshop Exercise (Biological Chemistry)

Part 1 - ANSWERS

NOTE to STUDENTS and FACILITATORS: One of the main purposes of the Workshops is to allow free exchange of information by **having each member of a Learning Community in turn answer one part** of a discussion question. As each student explains a term or gives a definition in their own words, it should allow for free verbal EXCHANGE and promote learning by interaction. **Try to insure that everyone in your Learning Community does a question or two and the purpose of the exercise is that they must EXPLAIN THEIR ANSWERS to the rest of the community.**

Exercise 1 Answers:

a. ***Matter*** is anything that takes up space and has mass.
The basic form of matter are the ***elements***, substances that can not be chemically broken down to other types of matter. 92 naturally occurring elements have been identified.
A ***compound*** is made up of 2 or more elements combined in a fixed ratio.

b. As a demonstrative example we'll use ***Water.*** H_2O is a compound composed of hydrogen& oxygen. Let's compare the physical properties of each element to those of the compound.

Hydrogen is a colorless, highly flammable **gaseous** element, which is the lightest of all gases and the most abundant element in the universe. Hydrogen has an atomic number of 1; atomic weight of 1.00797; melting point of -259.14°C; a boiling point of -252.8°C; a density at 0°C of 0.08987 gram per liter; and a valence of 1.

Oxygen is a nonmetallic element that occurs as a diatomic **gas**, $O_{2,}$ and in many compounds such as water and iron ore. It combines with most elements, is essential for plant and animal respiration, and is required for nearly all combustion. Oxygen has an atomic number of 8; atomic weight of 15.9994; a melting point of -218.4°C; a boiling point of -183.0°C; a gas density at 0°C of 1.429 grams per liter; and a valence of 2.

Water is a clear, colorless, odorless, and tasteless **liquid**. H_2O is essential for most plant and animal life and the most widely used of all solvents. Its freezing point is 0°C (32°F); its boiling point is 100°C (212°F); its specific gravity (4°C) is 1.0000; and its weight per gallon (15°C) is 8.337 pounds (3.772 kilograms).

The five other important biological molecules could get tough... use your imagination;
carbon dioxide (CO_2) vs. carbon monoxide (CO), sucrose (glucose + fructose) vs. lactose (glucose + galactose); ribose sugar vs. deoxyribose (minus one oxygen results in the sugars in DNA vs RNA), etc.......

c. **Mass**, in physics, is the quantity of matter in a body regardless of its volume or of any forces acting on it. There are two ways of referring to mass, depending on the laws of physics defining it. The physical volume or bulk of a solid body. The measure of the quantity of matter that a body or an object contains. The mass of the body is not dependent on gravity and therefore is different from but proportional to its weight.

Weight, a measure, expressed in pounds or grams, of the force of gravity on a body. A measure of the heaviness of an object. Because the weights of different bodies at the same location are proportional to their masses, weight is often used as a measure of mass. Unlike the mass, the weight of a body depends on its location in the gravitational field of the earth or of some other astronomical body.

d. **Table 1. Chemical Symbols**

Symbol	Element	Biological Molecule or Function
O	oxygen	water; component of air
C	carbon	glucose; element of organic molecules
H	hydrogen	fatty acids
N	nitrogen	amino acid
Ca	calcium	calcium carbonate, calcified connective tissue or bone
P	phosphorous	ATP
K	potassium	action potentials & nerve conduction
S	sulfur	cysteine
Na	sodium	action potentials & nerve conduction
Cl	chloride	resting potential of cells
Mg	magnesium	found in chlorophyll

Exercise 2 Answers

a. fill in the blanks = neutrons; 15, 15 16; P = 30.974.

b. Table 2. The Major Subatomic Particles.

Particle	Charge	Mass	Location
proton	+1	1 dalton	nucleus
neutron	0	1 dalton	nucleus
electron	-1	1/1,840th dalton	subshell orbitals

c. ***neutron*** An electrically neutral subatomic particle having a mass 1,839 times that of the electron; stable when bound in an atomic nucleus, and having a mean lifetime of approximately 1.0´10^{3} seconds as a free particle. It and the proton form nearly the entire mass of atomic nuclei.

proton A stable, positively charged subatomic particle in the baryon family having a mass 1,836 times that of the **electron**.

electron A stable subatomic particle in the lepton family having a rest mass of 9.1066 ´ 10^{-28} gram and a unit negative electric charge of approx. -1.

Dalton is the atomic mass unit ; a unit of mass equal to 1/12 the mass of the most abundant isotope of carbon, carbon 12, which is given a mass of 12.

Atomic Number is the number of protons in the nuclei of each element which characterizes that element. In a neutral atom, the atomic number also indicates the number of electrons.

Atomic Weight refers to the atomic mass of an atom. It is equal to the mass number and is measured in the atomic mass units of Daltons. Protons and neutrons have a mass of approximately 1 dalton.

Mass Number is an indication of the approximate mass of an atom and is equal to the number of protons and neutrons in the nucleus.

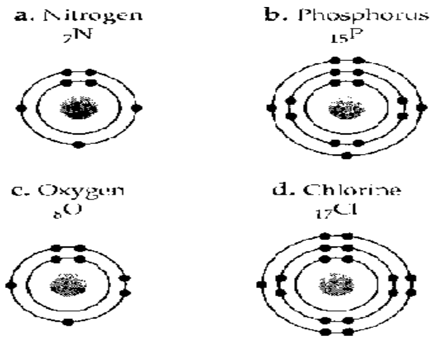
Isotope is one of atomic forms of an element, each containing a different number of neutrons and thus differing in atomic mass.

Radioactivity results from an isotope that is unstable in which the nucleus decays with a proton spontaneously converting to a neutron and thereby emitting a detectable subatomic particle and energy.

d. **1.** Absorb energy

2. Energy is released

3.



Exercise 3 **Concept Map Answers. (pg 2)**

a. protons **b.** atomic number **c.** element **d.** neutrons **e.** mass number or atomic number
f. isotopes **g.** electrons **h.** electron shells or energy levels **i.** valance shell

Exercise 4. Chemical Bonds, Molecules, and Water Answers

a. ***valence*** - The combining capacity of an atom or a radical determined by the number of electrons that it will lose, add, or share when it reacts with other atoms. A positive or negative integer is used to represent the valance capacity. The valences of copper are 1 & 2.

chemical bond - Any of several forces or mechanisms, especially the ionic bond and covalent bond, by which atoms or ions are bound in a molecule or crystal.

covalent bond - A type of strong chemical bond in which two atoms share one pair of electrons in a mutual valance shell

molecular formula - A type of chemical notation indicating only the total quantity of the constituent atoms present in a compound = $C_6H_{12}O_6$

structural formula - A type of chemical notation in which the constituent atoms present in a compound are drawn by jointed lines representing covalent bonds = H-O-H

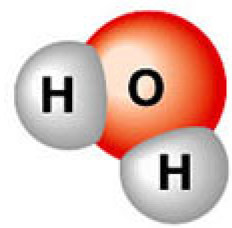
non-polar - when referring to a covalent bond, where the electrons forming the bond are shared equally between the tow atomic nuclei, i.e., no unequal distribution of charge

polar - if referring to a polar covalent bond, it's when one atom is more electronegative than the other, thus electrons forming the bond are not shared equally.

ionic bond - A chemical bond between two ions with opposite charges, characteristic of salts. Also called ***electrovalent bond.***

cation - an ion with a positive charges, produced by the loss of one or more electrons

anion - a negatively charged ion.



b. (1) 1 (2) 2 (3) 3 (4) 4

c. (1) $CaCl_2$ (2) Ca^{+2} is the cation

d. (1) A sketch of water is given to the right
(2) It is this slight angle asymmetry that renders water a polar molecule. Most of the physical properties of water that have made it a desirable molecule for the living condition, and have made it an excellent solvent depend upon this polarity of water.

e. Hexadecane lacks a hydrophilic group, as a carboxylic acid, and is therefore insoluble in an aqueous environment. Palmitate, although nearly identical in structure to hexadecane, has a hydrophilic carboxyl group, and is therefore amphipathic and partially soluble in an aqueous environment.

f. Having a single reaction repeatedly add the same monomer to form a long chain polymer means that a single enzyme or set of enzymes can be used to add each successive monomeric unit. Less energy needs to be invested in the genetic apparatus and an economy of simple repetition is achieved.

Table 3. The 30 Most Common Monomers in Cells

Molecule Type	# present in cells	Monomer Name	Role in Cell
Amino Acid	20	Alanine, Glutamate, Leucine, Serine Arginine, Glutamine, Lysine, Threonine Asparagine, Glycine, Methionine, Tyrosine Aspartate, Histidine, Proline, Tryptophan Cysteine, Isoleucine, Phenylalanine, Valine	Monomeric units of all proteins
Nucleotide	5	Adenosine, Cytosine, Guanosine, Thymidine, Uridine	Components of nucleic acids (DNA & RNA)
Sugars	2	Ribose and Glucose	Components of nucleic acids; Energy metabolism & components of starch & glycogen
Lipid	3	Glycerol, Choline, and Palmitate	Components of phospholipids

Table 4. Some Common Functional Groups Found in Biological Molecules							
Functional Group --->	carboxyl	phosphoryl	amino	hydroxyl	sulfhydryl	carbonyl	aldehyde
Its Structure --->	O || - C-O$^-$	O || - **P**-O$^-$ O$^-$	-NH$^+_3$	-OH	-SH	O || -C-	O || -C-H
Typical Molecule Containing this Group	amino acid fatty acid	ATP	amino acid, adenine guanine	glycerol, glucose, ribose, cholesterol	cysteine	guanine thymine uracil cytosine	glucose ribose
Form that predominates near neutral pH	N	N	P	U	U	U	U

N = Negatively Charged Groups @ Near Neutral pH of Cells P = Positively Charged Groups @ Near Neutral pH of Cells
U = Uncharged Groups @ Near Neutral pH of Cells, i.e., neutral but polar.

Exercise 6. The Fitness of Water

a. **T** - As a molecule with a dipole structure, i.e., having an unequal distribution of charge within its structure with one end being slightly positive and the other end slightly negative, water is able to easily form ionic like interactions with other polar molecules.

b. **T** - Biochemists call the biochemical reaction that links amino acids together to make proteins, like sugars together to make carbohydrates and link glycerol to three fatty acids to make fats ***condensation***. In this reaction a molecule of oxygen is reduced and the by-product, water, is made. In fact, this reaction of condensation, is one of the two most common biochemical reactions in living cells is reduction. It is a reaction in which electrons are transferred from a donor to an acceptor molecule, with a hydride ion (a proton and its electrons) being the most common form of the transfer mechanism. The reduction of oxygen, adding a hydrogen proton and its electron, results in the formation of water.

c. **F** - The density of ice, a solid, is less than its liquid form; that's why ice cubes float in your single malt scotch. Ecologically the evolutionary consequence is that lakes freeze from the top down, not the bottom up. If ice were denser then the pattern of evolution which has aquatic organism living in the silts of lake bottoms would not have occurred and the distribution of flora and fauna would be radically different than we see today.

d. **T** - Water easily forms hydrogen bonds, weak electrostatic intermolecular attractions, to other water molecules, thereby providing water with a greater tensile strength and cohesiveness that expected from the properties of a single water molecule. The tensile strength of water is one of the highest known for a liquid which means that the surface of water can support a greater weight of small object that expected (water bugs) and the energy required to break all those hydrogen bonds means that the transition from liquid to water (the heat of vaporization) is greater for water than it is for almost all liquids.

e. **T** - Water is a clear and colorless liquid meaning it allows visible light to pass through its structure without absorbing little to no energy. A consequence of water's translucence is that light can reach deep into large aquatic environments where aquatic plants can absorb the visible light for the process of photosynthesis and thermal energy absorption.

f. **X** - As far as evolutionary biologists and physiologists have been able to determine the fact that water is odorless and colorless has had no selective advantage to any living cell or the structure of the molecules in that cell. However, colorless water is important in vision, i.e., the fluids of the eye being colorless has selective advantage.

BioJeopardy Answers

a. What is ultraviolet radiation?
b. What is Heat of Vaporization of Water?
c. What is the activated form of a monomer?

Exercise 7. Answers

The challenge for this section is to give students an ability to work with the concepts of acid, base, and pH. This requires a working knowledge of logs. Some students will be totally unprepared for log problems. Your facilitator you may wish to review some of the fundamentals, such as the following:

$\log_a X + \log_a Y = \log_a XY$ $\quad\quad$ $\log_a X - \log_a Y = \log_a X/Y$ $\quad\quad$ $\log_a X^n = n \log_a X$

but, at any rate, be sure to remind the students that the definition of pH is:

pH is the negative log of the hydrogen ion concentration, thus

pH = x implies $[H^+] = 10^{-x}$ moles/liter

a. 2

b. 0

c. 1. 100 times as many **2.** 100 times as many (protons are hydrogen ions).

d. Fill in the Blanks in the following Table:

$[H^+]$	$[OH^-]$	pH	Acidic, Basic, or Neutral?
10^{-3}	10^{-11}	3	acidic
10^{-8}	**10^{-6}**	8	**basic**
10^{-12}	**10^{-2}**	**12**	**basic**
10^{-7}	10^{-7}	**7**	**neutral**
10^{-1}	**10^{-13}**	1	**acidic**

e. From Hint #1 : Consider pH 7, where $[H^+] = [OH^-]$, and pH 7 implies $[H^+] = 10^{-7}$ moles/liter,
so 10^{-7} moles/liter of water must have split.

From Hint #2: one mole of water weighs 18 gm, so in 1 liter or 1,000gm
there will be [1,000/18] or 55.55 moles of water.

Taking the rationale of the above two hints: The fraction of water molecules that are split
= [10^{-7} moles/liter] / [55.55 moles/liter] = 1.8×10^{-9}

Exercise 8. Chemistry of the Organics Answers. Often it does not make sense to write a molecular formula for the large organic molecules for their composition is variable. However, structural formulas are very informative:

		Molecular Formula	Structural Formula
A.	1) glucose	$C_6H_{12}O_6$	Figure 5.4 page 66 - Campbell 4th edition Figure 5.4 page 61 – 5th edition
	2) triglyceride	glycerol + 3 fatty acids Numbers of atoms is variable $C_{51}H_{98}O_6$ (tri-palmitate)	Figure 5.10 page 70 - Campbell 4th edition Figure 5.10 page 65 – 5th edition
	3) phospholipid	glycerol + 2 fatty acids + PO_4 and large organic as choline	Figure 5.12 page 72 – Campbell 4th edition Figure 5.12 page 67 - 5th edition
	4) amino acid	backbone = $N_1C_2O_2H_3$ + R	Figure 5.15 page 75 - Campbell 4th edition Figure 5.15 page 69 – 5th edition

B. Have one member of your Learning Community each, in turn, list one of the molecular forces involved in the structure of proteins and tell the others at what level of protein structure that force functions.

1. **hydrophobic forces** - a type of weak chemical "bond" formed when molecules that do not mix with water coalesce to exclude water. Most hydrocarbons, i.e., carbon and hydrogen covalently bonded regions, are hydrophobic. These forces are most involved with tertiary and quaternary structure of proteins.
2. **hydrophilic forces** - having an affinity of water; is a chemical attraction between polar regions of a molecule with the dipolar structure of water. These forces are most involved with tertiary and quaternary structure of proteins.
3. **hydrogen bonds** - A type of weak chemical bond formed between the slightly positive hydrogen atom of a polar

covalent bond in one molecule (which may often be water) that is attracted to the slightly negative atom of a polar covalent bond in another molecule (which can be another water molecule). These forces are most involved with secondary level of protein structure, but also can contribute to the tertiary and quaternary structure of proteins.

4. **Ionic bridges** can form a chemical bond between two ions with opposite charges, as in salts. These forces are most often involved with tertiary and quaternary structure of proteins.

5. **Peptide bond** is a covalent bond between two amino acids, between the amino group of one amino acid and the carboxyl group of another amino acid. This force is most prominent at the primary level of the structure of proteins.

6. **Disulfide bridges** are covalent bonds between one molecule of the amino acids cysteine and another cysteine molecule's sulfur atom. These bonds are most prominent at the tertiary and quaternary level of protein structure.

C. This question is to give the student a "feel" for polymers as linked monomer units containing various functional groups. Using their books to look up some of these answers, if necessary, students should notice the wide range of biological materials that are composed of polymers. We are supposedly getting them ready to for such important polymers as proteins and nucleic acids.
Starch and Glycogen are glucose monomers linked together through α1,4 glycosidic covalent bond linkages
Cellulose is made of glucose monomers linked together through β1,4 glycosidic covalent bond linkages
Insect exoskeletons is ***chitin***, an amino sugar whose structure is given on page 70.
Human hair, bird feathers, and reptile scales are made of α-***keratin***, a protein monomer.
Silk is a protein made of β-**keratin**, a protein monomer.

Exercise 9. Concept Maps Answers

A. Carbohydrates -

a. monosaccharides	b. $(CH_2O)_n$	c. energy sources
d. monomer precursors	e. covalent -glycosidic bond	f. dissacharides
g. polysaccharides	h. glycogen	i. Animals
j. starch	k. cellulose	l. chitin

B. Lipids -

a. fats	b. phospholipids	c. glycerol
d. fatty acids	e. unsaturated	f. saturated
g. phosphate	h. cell membrane	i. steroids
j. hormones		

Exercise 10. Answers to Discussion Problems

a. Significance

1. *electro-negativity* - describes how strongly a nucleus will attract electrons. In covalent bonds, the nucleus with the highest electro-negativity attracts electrons more strongly, resulting in a polar bond
2. *free radicals* - are reactive molecules with unpaired electrons implicated in both the cellular deterioration that accompanies aging, and the development of some diseases, including amyotrophic lateral sclerosis (Lou Gehrig's Disease), cancer, and atherosclerosis.
3. *carbon* - the atomic basis of life and the molecules of life. Carbon's ability to form 4 covalent bonds with other carbons and/or atoms has resulted in the evolution of hundreds of thousands of organic molecules.
4. *functional groups* - responsible for the physical properties and chemical reactivity of organic molecules.

b. It takes one calorie of energy to raise one gram of water one degree Celsius, which, relative to other liquids, is actually quite high. Much of the energy that is absorbed is used to disrupt the intermolecular hydrogen bonds that form as a result of the polar, asymmetric nature of the water molecule. Because energy is absorbed in breaking these weak bonds, the temperature of the water does not rise as much as that of another liquid might. In this sense, the temperature of a cell, because its milieu is aquatic, is "buffered" from shifts or changes in the temperature of the environment.